Cycling habits and other psychological variables affecting commuting by bicycle in the city of Madrid

Begoña Muñoz*
Researcher at TRANSyT - Transport Research Center
Universidad Politecnica de Madrid
c/ Profesor Aranguren s/n
28040 Madrid
Spain
Phone: +34 91 336 67 08; Fax: +34 91 336 53 62
Email: b.mlopez@upm.es

Andres Monzon
Professor of Transport. Department of Civil Engineering
Universidad Politecnica de Madrid
c/ Profesor Aranguren s/n – Ciudad Universitaria
28040 Madrid
Spain
Phone: +34 91 336 53 73
Email: andres.monzon@upm.es

David Lois
Assistant Professor at the Department of Social Psychology
Universidad Nacional de Educación a Distancia
C/ Juan del Rosal 10
28040 Madrid
Spain
Phone: +34 91 398 9698
Email: davidlois@psi.uned.es

*corresponding author

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ABSTRACT

In order to develop effective cycling policies it is important to know the factors influencing the use of the bicycle for daily mobility. Traditional discrete choice models tend to be based on variables such as time and cost, which do not sufficiently explain the choice of the bicycle as a mode of transportation. Since psychological factors have been identified as particularly influential in the decision to commute by bicycle, this paper examines the perceptions of different cycling factors, and their influence on commuting by bicycle. Perceptions are measured using attitudes, other psychological variables, and habits.

Statistical differences in the variables are established according to the choice of commuting mode and bicycle experience (commuter, sport/leisure, no use). This enabled us to identify the main barriers to commuting by bicycle, and to make recommendations for cycling policies. We identify two underlying structures (factors) among the attitudinal variables: “Direct Benefits” and “Long-term benefits”; and three other factors related to variables of difficulty: “Physical conditions”, “External facilities”, and “Individual capacities”. The effect of attitudes and other psychological variables on individuals’ decision to cycle to work/place of study is tested using a logit model. In the case study of Madrid (Spain), the decision to cycle to work/place of study is heavily influenced by cycling habits (for non-commuting trips). Since bicycle commuting is not common, attitudes and other psychological variables play a less important role in the use of bikes.

1. INTRODUCTION

The benefits of bicycle use are undeniable, both for users (in terms of health, flexibility, availability, cost, speed) and for society (low emissions, sustainability). As a result of these benefits, the bicycle as a transportation mode has become a key element of many transportation policies designed to foster sustainable development. Many countries, regions and cities have initiated policies supporting bicycle use. In Spain, these policies include measures such as creating cycling lanes and safe bicycle parking; improving bicycle-public transportation intermodality; and public bicycle sharing systems. These measures have fuelled a positive trend in bicycle use in Spain *(1)*. However, cycling levels are still low, especially for commuting trips.

In order to develop effective cycling policies, it is important to know the factors that influence the use of the bicycle for daily mobility. Traditional discrete choice models are mainly based on variables such as time and cost. These variables do not sufficiently explain the choice of the bicycle as a mode of transportation. Some researchers have noted a significant influence of psychological factors –such as attitudes, social norms, perceived behavioral control and habits– in the decision to commute by bicycle. Bicycle commuters show more positive attitudes towards bicycle use *(2-5)*; more perceived social norm or psychological support for using the bicycle *(2, 3, 6)*; more positive perceived behavioral control towards bicycle use *(2)*; and less perception of barriers *(4, 6)*. However, habits reduce the influence of these constructs in the decision to use the bicycle *(7)*. Habits of using other modes have a negative impact on bicycle use *(8)*; while the habit of using the bicycle for non-commuting mobility increases the frequency of bicycle use for commuting trips *(7, 9)*. In view of the fact that there is limited research on the relationship between attitudes, other psychological constructs and cycling *(10)*, this research project aims to continue analyzing the relationship between psychological factors and bicycle commuting following the research work of Heinen et al.*(5)*

The paper is organized as follows. The theoretical framework is presented in the second section. Descriptions of the case study, data collection and variables are included in the third section. Results are shown in the fourth section, which determines the differences between various types of users in their perceptions of cycling factors. On this basis, the main structures underlying the attitudinal and other psychological variables are identified and defined. The final part of the analysis examines the psychological factors influencing bicycle commuting through a binary logit model. Finally, section five contains some policy recommendations and conclusions.

2. FRAMEWORK

The framework of this paper is the Theory of Planned Behavior (TPB) *(11)*, which is the best-known and most widely supported attitudinal psychological theory in most studies relating to behavioral decisions. This theory has been used in various studies on cycling *(2, 5, 12)*, and in the field of active travel behavior *(7, 13)*. TPB states that attitudes toward a behavior, subjective norms, and perceived behavioral control combine to shape an individual's behavioral intention and final behavior, which in the case of our research is commuting by bicycle. These components are described by Ajzen *(14)* as follows: the attitude toward a behavior is “the degree to which performance of the behavior is positively or negatively valued”; the subjective norm is “the perceived social pressure to engage or not to engage in a behavior”; and the perceived behavioral control (PBC) refers to “people’s perceptions of their ability to perform a given behavior”. The descriptive norms, which were included by Ajzen and Fishbein *(15)* in a revision of the TPB in order to complete the subjective norm, have also been incorporated in this study. They are defined as perceptions of what others are doing. Some studies have shown that habit also has a significant influence on behavior, and specifically on bicycle use *(7)*. Therefore, habit has also been included as part of this research. All these elements have been applied to the study of cycling behavior, as shown in Figure 1.

This study focused on the choice of commuting mode to work or study: the mode used three or more times/week. It also takes into account the subjects’ cycling experience for purposes other than commuting. As can be seen in Figure 1, three categories are established for the analyses: (1)

whether or not the person commutes daily by bicycle: cycling commuter (CC) or non-cycling commuter (NCC); (2) according to commuting mode choice: bicycle (CC), pedestrian (P), public transport (PT), or car/motorbike (CM); and (3) whether the person has any bicycle experience: commuter cyclist (CC), sport/leisure cyclist (SLC), or non-cyclist (NC).

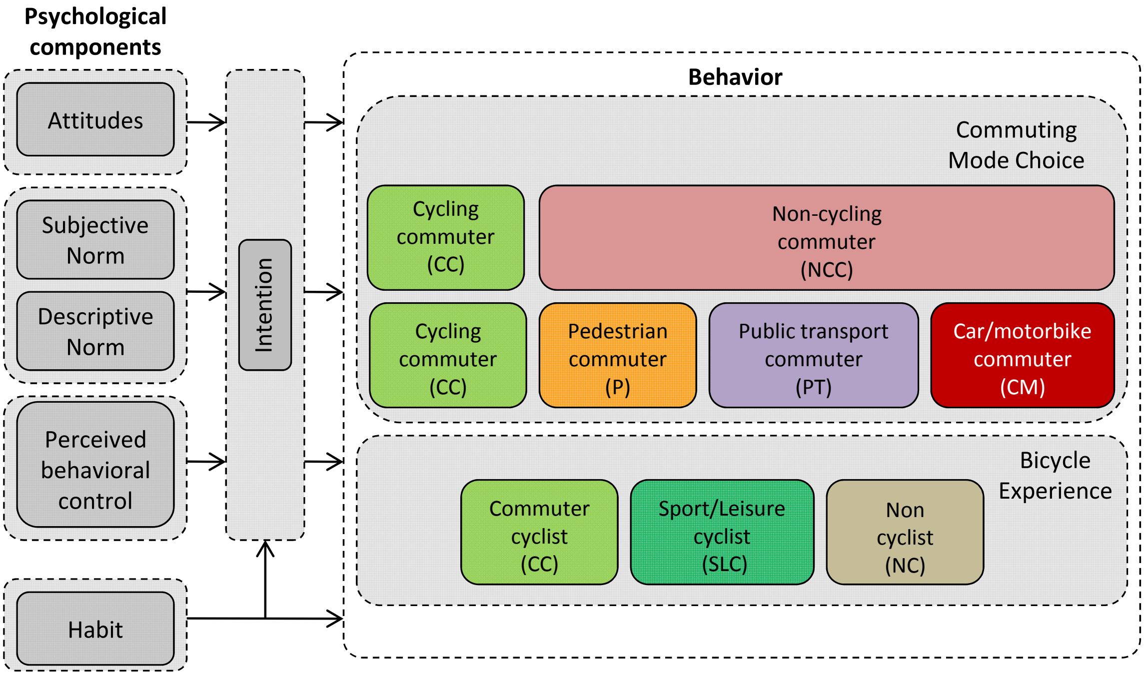

FIGURE 1 Application of the theory of planned behavior to cycling behavior.

Each psychological component was studied through several variables. A number of variables related to attitudes and to PBC were selected after a review of the literature on the reasons that encourage or discourage cycling. The most common reasons found in the literature are:

- **Positive**: health reasons/fitness, environmental awareness, perceived cost, speed, fun, flexibility, image prestige, relaxation, availability, reliability, ease of parking, and quality of life *(1, 4-6, 9, 16-18)*
- **Negative:** too dangerous, lacking sufficient fitness, lack of motivation, lack of facilities at work (showers, bike racks…), no bike lanes, personal safety during journey, bad weather, lack of proper lighting, distance, topography, safe parking at destination, lack of cycling knowledge or experience, too much traffic, uncomfortable, difficulties with trip-chaining, need to carry things, air pollution, free car-parking at work, lack of time, and bad road conditions *(3, 4, 6, 9, 16, 18-22)*

The attitudinal questions included all the positive and some of the negative reasons. The PBC questions included negative reasons, but only a limited number due to time/survey limitations. A summary of the variables used in the research can be seen in section 3.3.

3. METHODOLOGY

A three-step methodology was used to analyze the relationship between psychological factors and bicycle commuting. Psychological factors were measured by asking about perceptions of cycling factors. These were the variables used for the study. Firstly, statistical differences in the variables between different groups were determined: between cycling commuters and other mode commuters; and between commuter cyclists, sport/leisure cyclists and non-cyclists. This enabled us to identify the main barriers to commuting by bicycle. Secondly, an explanatory factor analysis was carried out to identify and define the main underlying structures among the attitudinal and perceived behavioral control variables. The appropriate summated scales for the rest of the variables (norms and habit) were also defined. Thirdly, a binary logit model was constructed based on the abovementioned factors and scales in order to determine the key psychological factors influencing bicycle commuting. SPSS®v18 was used as the statistical tool for the analyses.

3.1. The case study

Madrid is a dense city, with 3.2 million inhabitants. It has a mountainous topography, with differences of up to 200m. Madrid has a low cycling culture and bicycle use in the city center is 0.6% *(23)*. However, the local government is increasing its support for this mode, and progressively building a network of bicycle lanes and bicycle parks.

3.2. Survey description

The survey discussed in this paper was conducted as part of a municipal study to analyze the mobility demand and social impacts of two future cycling lanes in the city center of Madrid *(24)*. Behavioral aspects of cycling were introduced in the survey, as shown in the scheme in Figure 1.

The survey was conducted during working days, in the third week of September 2011. Surveys were short face-to-face on-street interviews, taking approximately 15 minutes. They were conducted on four streets in the center of Madrid. Since it was focused on residents' mobility, tourists were excluded.

The final valid sample was 224, which is a reasonable sample size. However, it is somehow limited for a detailed analysis of the comparison of the variables across different groups. The sample was designed according to the specific objectives of the municipal study, and consisted of 40% cyclists, 20% pedestrians, 20% public transport users and 20% car/motorbike users. Today, the modal split in the city center of Madrid is as follows: 0.6% cycling trips, 37.4% walking trips, 39.0% public transport trips, and 23.0% car/motorbike trips *(23)*. Consequently, the sample is not representative of mobility.

Perceptions of cycling factors were got through two different types of questions: those involving attitudes and those related to the control of bicycle use (perceived behavioral control-PBC). The questionnaire also included several questions related to subjective and descriptive norms, and mobility habits. There were also socio-economic questions and others on issues such as parking availability, use of public transport travel-card, and perceptions of cycling facilities in Madrid. The results of the survey enabled us to assess the psychological components of cycling decisions.

3.3. Valuation of psychological components

Psychological components were measured by asking about attitudinal beliefs, descriptive norm beliefs, and perceived behavioral control beliefs, as can be seen in Table 1. The subjective norm was calculated as its respective beliefs weighted by the corresponding importance.

TABLE 1 Psychological Components Valuation

					Mean	Std. Dev.
Attitudinal beliefs toward bicycle characteristics						
Question: "*Considering the characteristics of the bicycle as a mode of transportation, evaluate to what extent you agree with the following*". (range: 0 to 10)						
Environmental benefits					9.75	0.73
Health benefits					9.21	1.67
Quality of life					9.16	1.65
Cheap					9.16	1.32
Available					9.00	1.59
Flexible/Independent					8.41	2.12
Easy to park					8.21	2.36
Fun					8.00	2.11
Quick					7.67	2.30
Image prestige					7.56	2.22
Reliable					7.42	2.46
Comfortable					7.13	2.30
Relaxing					7.04	2.51
Traffic safety (Safe, without accidents)					5.19	2.37
Weather independent (Independent of weather)					4.73	2.89
Subjective norm toward bicycle commuting - Aggregated value (range: 0 to 100) (Scale: 3 items; Cronbach's α = 0.90)					29.57	28.66
Subjective Norm	Belief		Importance			
Family	6.98	x	4.77	=	34.63	33.43
Friends	7.29		3.84		29.71	31.50
Co-workers/fellow students	6.78		3.23		24.51	29.29
Descriptive norm beliefs toward bicycle commuting - Aggregated value (Scale: 5 items; Cronbach's α = 0.72)					4.76	1.91
Question: "*To what extent do you think bicycle use has increased in Madrid among the following groups of people*?" (range: 0 to 10)						
Young people					7.21	2.19
People in general					6.31	2.11
Friends					4.26	3.23
Co-workers/fellow students					3.44	3.05
Family members					2.50	3.21
Perceived behavioral control beliefs toward bicycle commuting						
Question: "*To what extent do you consider it possible (or it would be possible) to commute by bicycle, considering the following factors*?" (range: 1 to 4)						
Safe parking at home					3.25	1.12
Physical fitness					3.08	1.04
Safe parking at destination					2.78	1.19
Cycling in traffic					2.65	1.20
Facilities at destination					2.56	1.18
Topography					2.35	1.02
Distance					2.25	1.06
Traffic aggression					1.94	0.99
Cycling Habit (range: 0 to 5) (Scale: 5 items; Cronbach's α = 0.80)					0.84	1.56

Cycling habit was measured following the response frequency measure established by Verplanken et al *(25)*. Respondents were asked "Which mode of transportation do you use most frequently for the following activities?" A five-item version of the original response frequency measure was used, including five non-commuting trip purposes: shopping for daily consumer items; going shopping; accompanying children/the elderly; going out (restaurants, cinema…); and visiting family or friends. The strength of cycling habit is indexed by the number of choices of the bicycle mode.

Table 1 shows the valuation of the main variables used. All variables have been treated as scalars, as we have adopted the same distance between valuations as the hypothesis. Mean scores are shown in parentheses from now on. The appropriate summated scales for the variables of subjective norm, descriptive norm and habit have been defined; and their corresponding Cronbach's alpha coefficients have been calculated. Cronbach's alpha coefficient is a weighted average of the correlations between the variables of a scale. It is used to measure the internal consistency or reliability of a scale (*26*). In this case, all Cronbach's alpha coefficients are greater than the suggested minimum acceptable level of 0.7 *(27)*, indicating that internal consistency is acceptable, and it is therefore acceptable to use the summated scales instead of the original variables.

The highest scores among **attitudinal** beliefs correspond to *Environmental benefits* (9.75), *Health benefits* (9.21), *Quality of life* (9.16) and *Cheap* (9.0). The lowest averages correspond to *Weather independent* (4.73) and *Traffic safety* (5.19). With regard to the **subjective norm** belief, *Friends* scores the highest value (7.29), which indicates that friends' support is considered the most positive. However the most important influencing group is *Family* (4.77). As a result, the highest perceived social pressure to commute by bicycle comes from the *Family*, followed by *Friends*, and *Co-workers/fellow students*. Referring to the **descriptive norm** beliefs, the respondents consider that *Young people* are the group that is increasing its use of the bicycle the most (7.21). In contrast, respondents' *Family members* are seen as the group that has increased their bicycle use the least (2.50). *Safe parking at home* is the **perceived behavioral control** factor with the highest average score (3.25), followed by *Physical fitness* (3.08) and *Safe parking at destination* (2.78). This means that respondents show fewer difficulties in relation to these factors. However, *Traffic aggression* shows the lowest control value (1.94), hence it is the largest barrier to overcome. On average, the bicycle is more frequently used for 0.84 times of the five non-commuting trip purposes described. Therefore, the cycling habit in the sample is very low.

4. EMPIRICAL APPLICATION

4.1. Descriptive analysis

Considering the categories, the sample is distributed:

- According to the commuting mode choice:
  - ✓ 27% cycling commuters (CC)
  - ✓ 73% non-cycling commuters (NCC):
    - 12% pedestrians (P)
    - 39% public transport (PT): bus (8.0%), subway/railway (30.5%), and cab (0.5%).
    - 22% car/motorbike (CM): by car (17%), and by motorbike (5%).
- According to the bicycle experience:
  - ✓ 27 % commuter cyclists (CC)
  - ✓ 27% sport/leisure cyclists (SLC)
  - ✓ 46% non-cyclists (NC)

Most respondents are male (59%), with the 25-34 age group most heavily represented. It is also worth noting that 16% of the sample is foreigners, mostly in the younger age groups (up to

45). 59% of respondents have car/motorbike availability to commute. However, only 22% of them use it for their commuting trips. The remaining potential car/motorbike users mainly choose public transport (18%), cycling (12%), or walking (7%). The majority of the respondents (72%) are able to ride a bicycle and have a bicycle available for their daily trips. However, only 38% of them (27% of all respondents) choose the bicycle for commuting.

4.2. Comparisons across groups

This subsection analyzes whether there are any statistical differences in the mean score of the variables between different groups. Since we are conducting multiple comparison tests it is necessary to use adjusted P-values. The adjusted P-value for a particular hypothesis within a collection of hypotheses is the smallest overall significance level at which the particular hypothesis would be rejected (*28*).

Table 2 shows that cycling commuters value all bicycle characteristics more positively than non-cycling commuters, as was expected. The most positive cycling commuters' attitudinal beliefs correspond to the variables *Environmental benefits* (9.84), *Health benefits* (9.51) and *Quality of life* (9.51). The lowest value for cycling commuters is shown by the variable *Traffic safety* (6.10), while for non-cycling commuters, it is the characteristic *Weather independent* (4.18), followed by *Traffic safety* (4.85). Referring to the non-cycling commuter group, pedestrians and public transport commuters are attitudinally close to cyclists, while the lowest values for most variables are given by car/motorbike commuters. According to bicycle experience, the attitudinal beliefs of sport/leisure cyclists appear to be midway between commuter cyclists and non-cyclists. All these differences between groups are statistically significant for the variables: *Quick, Traffic safety, Reliable, Comfortable, Flexible/Independent, Weather independent, Relaxing, Fun* and *Quality of Life*. *Easy to park* shows statistically significant differences only for the second grouping.

Since the purpose of cycling policies is to shift trips from car/motorbike to bicycle, we looked at the differences in the factor valuation for car/motorbike and bicycle users. The variables *Quick, Comfortable, Flexible/Independent, Weather independent, Reliable* and *Relaxing* show the greatest differences between cycling commuters and car/motorbike commuters. Most car/motorbike commuters do not use the bicycle at all (60%). Therefore, differences between these factors are influenced by the lack of knowledge of the cycling experience itself by car/motorbike commuters (*29*).

TABLE 2 Attitudinal beliefs toward bicycle characteristics (NCC compared to CC)

	Reference group	Aggregated		Mode choice for NCC				Bicycle use for NCC		
	CC (61) Mean	NCC (163) Mean	Sig* (Ref. to CC)	P (26) Mean	PT (87) Mean	CM (50) Mean	Sig* (Ref. to CC)	SLC (61) Mean	NC (102) Mean	Sig* (Ref. to CC)
Quick	8.85	7.23	0.000	7.73	7.40	6.66	0.000	7.85	6.85	0.00
Environmental benefits	9.84	9.71	0.092	9.58	9.82	9.60	0.128	9.79	9.67	0.15
Cheap	9.46	9.04	0.017	9.23	8.99	9.04	0.057	9.11	9.00	0.10
Available	9.39	8.86	0.025	8.69	9.05	8.62	0.070	8.92	8.82	0.07
Traffic safety	6.10	4.85	0.000	4.62	4.93	4.84	0.000	5.38	4.54	0.00
Reliable	8.77	6.91	0.000	7.00	6.92	6.86	0.000	7.77	6.40	0.00
Health benefits	9.51	9.09	0.150	9.31	9.21	8.78	0.057	9.36	8.93	0.23
Comfortable	8.23	6.71	0.000	6.81	6.99	6.18	0.000	7.70	6.12	0.00
Flexible/Independent	9.33	8.07	0.000	8.12	8.48	7.32	0.000	8.59	7.75	0.00
Weather independent	6.20	4.18	0.000	4.35	4.08	4.26	0.000	5.26	3.53	0.00
Relaxing	8.20	6.61	0.000	6.50	6.78	6.36	0.000	7.77	5.91	0.00
Fun	8.92	7.65	0.000	7.35	7.85	7.46	0.000	8.57	7.10	0.00
Image prestige	7.85	7.45	0.390	7.54	7.28	7.72	0.480	7.52	7.41	0.43
Easy to park	8.54	8.08	0.037	8.19	8.17	7.86	0.000	8.77	7.67	0.16
Quality of life	9.51	9.03	0.007	8.92	9.24	8.72	0.013	9.38	8.82	0.02

*Mann–Whitney (U) test when 2 groups and Kruskal–Wallis (H) test when 3 or 4 groups. Adjusted significance levels: $p < (0.05/15) = 0.003$; $p < (0.10/15) = 0.007$ (Significant differences shown in gray).

Differences in average perceived social pressure (subjective norm) to commute by bicycle only appear to be statistically significant between bicycle use groups (Table 3). With regard to the descriptive norm, its corresponding scale shows statistically significant differences for the three groupings. Perceptions of an increase in bicycle use can be seen to be more positive in cycling commuters, followed by public transport commuters, pedestrians, and car/motorbike commuters. The descriptive norm is also higher for sport/leisure cyclists than for non-cyclists, but lower than for commuter cyclists.

A comparison of the mean score of the perceived behavioral control beliefs toward bicycle commuting variables (PBC variables) between groups shows that cycling commuters give the highest scores (Table 4). This indicates that their difficulties in using the bicycle to commute are lower than the corresponding difficulties for non-cycling commuters. As for the total sample, the variables *Traffic aggression, Distance,* and *Topography* are the greatest difficulties both for cycling and non-cycling commuters. With reference to non-cycling commuters, public transport commuters and car/motorbike commuters perceive all difficulties to be more important than any other group. Therefore in this case only pedestrians appear to be close to cycling commuters. According to bicycle experience, the barriers decrease as cycling experience increases. All these differences between groups are statistically significant except for the variables *Facilities at destination, Safe parking at destination,* and *Traffic aggression*.

TABLE 3 Subjective and descriptive norm toward bicycle commuting (NCC compared to CC)

	Reference group	Aggregated		Mode choice for NCC				Bicycle use for NCC		
	CC (61) Mean	NCC (163) Mean	Sig* (Ref. to CC)	P (26) Mean	PT (87) Mean	CM (50) Mean	Sig* (Ref. to CC)	SLC (61) Mean	NC (102) Mean	Sig* (Ref. to CC)
Subjective norm scale	32.20	28.59	0.567 [1]	29.54	30.15	25.38	0.682 [1]	34.75	24.90	0.066 [1]
Family	33.02	35.23	0.739 [2]	37.54	36.34	32.10	0.866 [2]	41.13	31.71	0.201 [2]
Friends	33.92	28.13	0.362 [2]	27.85	30.07	24.90	0.620 [2]	34.41	24.37	0.096 [2]
Co-workers/fellow students	29.61	22.60	0.178 [2]	23.35	24.38	19.12	0.273 [2]	29.74	18.33	0.015 [2]
Descriptive norm scale	n=59 5.30	n=158 4.56	0.011 [1]	n=25 4.58	n=86 4.66	n=47 4.38	0.068 [1]	n=59 5.03	n=99 4.29	0.002 [1]
People in general	n=59 6.73	n=158 6.15	0.021 [3]	n=25 6.20	n=86 6.10	n=47 6.21	0.130 [3]	n=59 6.47	n=99 5.96	0.023 [3]
Young people	n=58 7.38	n=158 7.15	0.351 [3]	n=25 7.40	n=86 7.17	n=47 6.98	0.734 [3]	n=59 7.07	n=99 7.20	0.646 [3]
Family members	n=56 2.98	n=155 2.32	0.188 [3]	n=25 1.72	n=84 2.61	n=46 2.13	0.257 [3]	n=57 3.33	n=98 1.73	0.007 [3]
Friends	n=58 5.24	n=158 3.90	0.003 [3]	n=25 4.24	n=86 3.86	n=47 3.79	0.027 [3]	n=59 4.85	n=99 3.33	0.000 [3]
Co-workers/fellow students	n=56 4.02	n=157 3.24	0.104 [3]	n=25 3.32	n=86 3.49	n=47 2.72	0.226 [3]	n=59 3.34	n=98 3.17	0.262 [3]

*Mann–Whitney (U) test when 2 groups and Kruskal–Wallis (H) test when 3 or 4 groups. (Significant differences shown in gray).
1: Significance levels: $p < 0.05$; $p < 0.10$.
2: Adjusted significance levels: $p < (0.05/3) = 0.017$; $p < (0.10/5) = 0.033$
3: Adjusted significance levels: $p < (0.05/5) = 0.010$; $p < (0.10/5) = 0.020$

TABLE 4 PBC beliefs toward bicycle commuting (NCC compared to CC)

	Reference group	Aggregated		Mode choice for NCC				Bicycle use for NCC		
	CC (61) Mean	NCC (163) Mean	Sig* (Ref. to CC)	P (26) Mean	PT (87) Mean	CM (50) Mean	Sig* (Ref. to CC)	SLC (61) Mean	NC (102) Mean	Sig* (Ref. to CC)
Distance	2.59	2.13	0.002	2.73	2.06	1.94	0.000	2.20	2.09	0.007
Topography	2.70	2.22	0.001	2.81	2.14	2.06	0.000	2.49	2.06	0.000
Physical fitness	3.48	2.94	0.001	3.00	2.91	2.96	0.007	3.31	2.72	0.000
Facilities at destination	2.80	2.47	0.063	2.77	2.43	2.40	0.147	2.52	2.44	0.161
Safe parking at destination	2.62	2.84	0.227	2.77	2.82	2.92	0.596	2.82	2.85	0.477
Safe parking at home	3.23	3.25	0.605	2.88	3.23	3.48	0.085	3.72	2.97	0.000
Cycling in traffic	3.11	2.48	0.000	2.54	2.41	2.56	0.005	2.85	2.25	0.000
Traffic aggression	2.02	1.91	0.568	2.04	1.95	1.76	0.539	1.93	1.89	0.821

*Mann–Whitney (U) test when 2 groups and Kruskal–Wallis (H) test when 3 or 4 groups. Adjusted significance levels: $p < (0.05/8) = 0.006$; $p < (0.10/8) = 0.013$. (Significant differences shown in gray).

Rating all these cycling barriers according to differences between cycling commuters and car/motorbike commuters, we can see that:

- Cycling commuters give the highest scores to all variables, except for *Safe parking at home*, and *Safe parking at destination*. This shows that non-users do not perceive problems related to parking the bicycle.
- Variables such as *Distance, Topography, Cycling in traffic* and *Physical fitness*, which are widely perceived as barriers to bicycle use, provoke fewer difficulties to cycling commuters than to non-cycling commuters. Thus, differences in these variables seem to be the consequence of ignorance about the cycling experience itself by car/motorbike commuters (*29*). These difficulties can therefore be overcome by the cycling experience.
- Variables that affect both types of commuters (*Traffic aggression, Facilities at destination, Safe parking at home,* and *Safe parking at destination*) cannot be overcome by the cycling experience. Therefore, cycling policies should focus on these variables.

While comparing bicycle habit for non-commuting trips between groups, all differences are statistically significant (Table 5).Cycling commuters show a greater cycling habit (1.61) than non-cycling commuters (0.08). This indicates that cycling commuters also use this mode for non-commuting trips such as shopping, visiting friends, and so on. Non-cycling commuters use the bicycle mainly for sport (which is not included in this measure of bicycle habit); hence their bicycle habit is very low.

TABLE 5 Bicycle habit - For non-commuting trip purposes, except sport (NCC compared to CC)

	Reference group	Aggregated		Mode choice for NCC				Bicycle use for NCC		
	CC (61) Mean	NCC (163) Mean	Sig* (Ref. to CC)	P (26) Mean	PT (87) Mean	CM (50) Mean	Sig* (Ref. to CC)	SLC (61) Mean	NC (102) Mean	Sig* (Ref. to CC)
Habit	1.61	0.08	0.00	0.12	0.08	0.06	0.00	0.21	0.00	0.00

*Mann–Whitney (U) test when 2 groups and Kruskal–Wallis (H) test when 3 or 4 groups. Significance levels: p < 0.05; p < 0.10. (Significant differences shown in gray).

4.3. Factor analysis

An exploratory factor analysis was used to reduce the number of attitudinal and perceived behavioral control variables, and to identify their main underlying structures (factors). Variables with high correlation are components of the same factor. Table 6 shows the association of variables, and defines two factors for attitudinal variables and three factors for perceived behavioral control variables.

The characteristics *Cheap, Available, Image prestige* and *Easy to park* were removed from **attitudinal beliefs** due to low communality (<0.30). Direct and long-term benefits are the new factors identified, and explain a variance of 49.18%. The importance of "Direct benefits" comes from bicycle characteristics, such as *Reliable* and *Comfortable*. The second factor "Long-term benefits" is mainly defined by characteristics such as *Health benefits* and *Quality of life*, and to a lesser extent, by *Flexible/Independent* and *Environmental benefits*.

For **perceived behavioral control beliefs**, *Traffic aggression* was removed due to low communality (<0.20). We identified three factors explaining the 49.19% variance. "Physical conditions" is explained by the *Distance* and *Topography* variables. The second factor, "External facilities", is linked to parking and other facilities. The third factor is mainly defined by the variable *Physical fitness*, and is therefore designated "Individual capacities".

The assumptions underlying factor analysis were previously checked *(27)*: minimum sample size (224 > 5*15 items of attitudes; 224 > 5*8 items of PBC), and multicollinearity (Barttlet test: Sig = 0.00; MSA > 0.6). The Oblimin rotation (with delta zero) was used to find the factors. Factor scores were calculated with the Anderson-Rubin method.

TABLE 6 Correlations between factors and attitudes/PBC variables

Attitudinal beliefs toward bicycle characteristics	Factor		PBC beliefs toward bicycle commuting	Factor		
	Direct benefits	Long-term benefits		Physical conditions	External facilities	Individual capacities
Reliable	0.78		Distance	0.87		
Comfortable	0.68		Topography	0.61		
Traffic safety	0.64		Safe parking at destination		0.83	
Weather independent	0.62		Safe parking at home		0.54	
Quick	0.52		Facilities at destination		0.41	
Health benefits		0.75	Physical fitness			0.86
Quality of life		0.70	Cycling in traffic			0.47
Flexible/Independent		0.65				
Environmental benefits		0.55				
Fun		0.43				
Relaxing		0.43				

Values below 0.4 are not reported

4.4. Explanatory factors of cycling behavior

A binary logit model was used to observe the effect of attitudes and other psychological variables on the decision to commute by bicycle or to choose another mode. The dependent variable "Bicycle commuter" is obtained from the survey, and it is equal to 1 if the respondents commute daily by bicycle and 0 otherwise. The factors and scales calculated in the previous sections are the independent variables. The estimation of the discrete choice model was made using the software SPSS, seeking the model with best explanatory power. The influence of socio-demographic variables is partially incorporated in the model. These are treated as previous variables, influencing the formation of attitudes, social norms and perceived behavioral control (*30*).

The variables of the first model (model 1) include attitudes, norms, and perceived behavioral control. The results of this model show that "Direct benefits" and "Individual capacities" appear to significantly influence the likelihood of cycling to work/place of study (Table 7). A positive perception of the bicycle's direct benefits (*Reliable, Comfortable, Traffic safety, Weather independent*, and *Quick*), and a positive perception of "Individual capacities" (*Physical fitness,* and *Cycling in traffic*) positively affects the decision to cycle for commuting purposes (β=1.23 and β=0.42 respectively).

If bicycle *Habit* is included (model 2), the choice process is mainly influenced by current habit. Respondents with bicycle habit for purposes other than commuting (except sport) have a greater likelihood of cycling to work/place of study (β=1.74). This variable shows the greatest Odd Ratio (5.68), and means that with every unit of increase in *Habit*, the increase in the likelihood of that person being a cycling commuter is multiplied by 5.68. "Direct benefits" loses explanatory power (β from 1.23 to 1.02), and "Individual capacities" is not statistically significant. Since the chi-squared LR Test (61.03) is more than the critical value (3.84 for $p < 0.05$), model 2 (including habit) is an improvement over model 1 (without habit).

TABLE 7 Results of logistic regressions of cycle commuting

Variables	Model 1			Model 2		
	B	Sig.	Exp(B)	B	Sig.	Exp(B)
Attitudinal factor 1: Direct benefits	1.23	0.00	3.44	1.02	0.00	2.78
Attitudinal factor 2: Long-term benefits	0.31	0.23	1.37	0.05	0.85	1.05
Subjective norm	0.00	0.81	1.00	0.01	0.41	1.01
Descriptive norm	0.03	0.73	1.03	-0.01	0.97	1.00
PBC factor 1: Physical conditions	0.22	0.23	1.25	0.23	0.33	1.26
PBC factor 2: External facilities	-0.15	0.41	0.86	-0.13	0.58	0.88
PBC factor 3: Individual capacities	0.42	0.05	1.52	0.20	0.43	1.22
Cycling habit	-	-	-	1.74	0.00	5.68
Constant	-1.62	0.00	0.20	-2.30	0.00	0.08
	N = 217 Model Chi-Squared = 54.81 Cox and Snell R^2 = 0.22			N = 217 Model Chi-Squared = 115.84 Cox and Snell R^2 = 0.41		

5. CONCLUSIONS AND POLICY RECOMMENDATIONS

This paper examines perceptions of different cycling factors and their influence on bicycle commuting. Perceptions were measured using psychological constructs: attitudes, social norms, perceived behavioral control (PBC) –people's perceptions of their ability to perform a given behavior–, and habit.

Firstly, statistical differences of the variables were determined between cycling commuters and commuters by other modes; and between commuter cyclists, sport/leisure cyclists and non-cyclists. The main barriers to commuting by bicycle affecting different types of commuters were identified. These results can be used to reorient cycling policy efforts in order to achieve visible improvements in commuting by bicycle in Madrid.

The study confirms that cycling commuters value all cycling factors more positively than non-cycling commuters *(2-5)*. It also demonstrates that their difficulties in using the bicycle to commute are lower than the corresponding difficulties for non-cycling commuters *(2, 4, 6)*. Moreover, the findings show that increasing the cycling experience (including sport) increases the valuation of attitudinal beliefs, and decreases the barriers to commuting by bicycle. Car/motorbike commuters are the most strongly opposed to cycling commuters, showing the greatest differences. These differences indicate that negative perceptions from car/motorbike commuters (the bicycle is slow, uncomfortable, inflexible, weather dependent, unreliable, and stressful), and their barriers (*Distance, Topography, Cycling in traffic,* and *Physical fitness*) could be improved by policies that allow non-cycling commuters to experience cycling more easily. For example: measures that allow easy daily access to bicycles (public bike sharing); free availability of bicycles in companies for employees; tax discounts when buying a bicycle; integration with public transportation.

Traffic safety is the worst perceived attitudinal factor for cycling commuters and the second worst for other commuters. Moreover, all respondents show more difficulties in relation to *Traffic aggression* (PBC item). This highlights a real problem in the relationship between bicycles and motorized traffic in the congested city center of Madrid. This paper demonstrates that this problem cannot be solved simply by increasing the cyclist commuting experience. It is also necessary to provide dedicated cycle lanes, restrict car access, and implement traffic calming in certain areas.

Other factors involving bicycle facilities (lack of showers or bike racks at destination, lack of safe parking at home or at destination) are also impossible to resolve through the cycling experience. These variables should therefore be included as measures in the cycling mobility strategy of local administrations and organizations.

In the case study, *Family* is the social group with the most positive influence on the decision to commute by bicycle. Moreover, *Young people* are seen as the group which is increasing its bicycle use the most in Madrid. Therefore cycling publicity campaigns should have a twofold objective: to encourage families to support more bicycle use, and to dispel the image of bicycles as being only for young people.

Secondly, two underlying structures (factors) have been identified among the attitudinal variables: “Direct Benefits” and “Long-term benefits”. As for PBC variables, three other factors are relevant: “Physical conditions”, “External facilities”, and “Individual capacities”. Thirdly, the effects of attitudes, norms, PBC and habit have been tested for cycling to work/place of study. Choosing the bicycle as a commuting mode is mainly defined by the existence of bicycle habit for non-commuting trips. Attitudes related to direct benefits in terms of reliability, comfort and time are influential on the choice of the bicycle as a commuting mode, but to a lesser extent than habit. This result represents the case of a city with low bicycle use, which is in contrast with cases where cycling is a normal practice. In cycling cities, both habit and TPB factors (attitudinal direct benefits and PBC) show a significant influence on cycling commuting *(5)*. The social and physical context, as well as the method of measuring the PBC (disaggregated in several items in the present study) might explain the different results.

Some of the aforementioned policies could foster non-commuters to start experiencing cycling, and then to develop their habit for non-commuting trips and finally for commuting. Thus Park et al. (*31*) point out that 57% of commuter cyclists began as leisure-cyclists. However, the increase in the number of commuting trips must come from motorized trips in order to maintain high levels of pedestrians and public transport users. When the bicycle is considered to be a real mode of transportation in the city, the importance of attitudes, norms and PBC is likely to increase, as bicycle use is less dependent on habit.

This is the first application of the TPB model in a context with low bicycle modal share. This research can therefore be used as a case study, since it is likely to be highly comparable to other locations with a low cycling mode share. Moreover, this application has used disaggregated measures of subjective norm, descriptive norm, and PBC. Further development of the proposed model could be a hybrid model, including the relationship between the physiological variables and other socio-demographic and socio-economic variables.

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